AMENDMENT TO THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the application:

LISTING OF CLAIMS

1 – 120 (cancelled)

121. (new) A geometric pattern matching apparatus for refining the pose of an object in a run-time image, the object having an expected shape and a true pose in the run-time image, the apparatus comprising:

a training module adapted to receive a training image, and to provide a stored model pattern, the stored model pattern including a geometric description of the expected shape of the object, the geometric description including a plurality of pattern boundary points; and

a run-time module adapted to:

receive the stored model pattern, a starting pose, and the run-time image, the starting pose representing an initial estimate of the true pose of the object in the run-time image;

detect in the run-time image a plurality of image boundary points; and

provide, using the stored model pattern, the starting pose, and the plurality of image boundary points:

a refined pose, the refined pose representing a refined estimate of the true pose of the object in the run-time image;

an error value;

an aggregate clutter value; and

an aggregate coverage value.

122. (new) The apparatus of claim 121, wherein the run-time module is also adapted to:

receive a coordinate transformation that maps points in an orthonormal coordinate system to points in the image; and

use said coordinate transform to determine at least one degree of freedom of the refined pose.

123. (new) The apparatus of claim 121, wherein the run-time module is also adapted to:

determine, using the starting pose and the model pattern, an evaluation of reliability of at least some of the plurality of image boundary points, and a corresponding position along a boundary of the model pattern corresponding to at least some of the plurality of image boundary points.

124. (new) The apparatus of claim 123, wherein the refined pose is computed using the starting pose, the plurality of image boundary points, evaluations, and corresponding positions.

125. (new) The apparatus of claim 121, wherein the run-time module is also adapted to:

provide an evaluated pattern boundary point list that identifies boundary points in the stored model pattern that are not present in the run-time image.

126. (new) The apparatus of claim 121, wherein the run-time module is also adapted to:

provide an evaluated image boundary point list that identifies boundary points in the run-time image that are not present in the stored model pattern.

127. (new) The apparatus of claim 121, where the error value is a root-mean-squared error value.

128. (new) The apparatus of claim 121, wherein the starting pose is determined by a template matching method.

129. (new) The apparatus of claim 128, wherein said template matching method employs normalized correlation.

130. (new) The apparatus of claim 128, wherein said template matching method uses digital re-sampling to determine at least one degree of freedom of the starting pose.

131. (new) The apparatus of claim 121, wherein the starting pose is determined by a generalized Hough transform.

132. (new) The apparatus of claim 121, wherein the starting pose is a six degree-of-freedom coordinate transformation.

133. (new) The apparatus of claim 121, wherein the starting pose is a coordinate transform that includes non-translational degrees of freedom.

134. (new) The apparatus of claim 121, wherein the refined pose is a six degree-of-freedom coordinate transformation.

135. (new) The apparatus of claim 121, wherein the refined pose is a coordinate transform that includes non-translational degrees of freedom.

136. (new) The apparatus of claim 121, wherein the run-time module is also adapted to:

compute an evaluated pattern boundary point list that provides, for each of a plurality of said pattern boundary points, a numerical evaluation of the likelihood that the pattern boundary point was present in the run-time image.

137. (new) The apparatus of claim 121, wherein the run-time module is also adapted to:

compute an evaluated image boundary point list that provides, for each of a plurality of said image boundary points, a numerical evaluation of the likelihood that the image boundary point was present in the stored model pattern.

138. (new) A geometric pattern matching method for refining the pose of an object in a run-time image, the object having an expected shape and a true pose in the run-time image, the method comprising:

receiving a training image;

receiving a starting pose, the starting pose representing an initial estimate of the true pose of the object in the run-time image;

receiving a run-time image;

using the training image to provide a stored model pattern, the stored model pattern including a geometric description of the expected shape of the object, the geometric description including a plurality of pattern boundary points;

using the stored model pattern, the starting pose, and the run-time image to detect in the run-time image a plurality of image boundary points; and

using the stored model pattern, the starting pose, and the plurality of image boundary points to provide:

a refined pose, the refined pose representing a refined estimate of the true pose of the object in the run-time image;

an error value;

an aggregate clutter value; and

an aggregate coverage value.

139. (new) The method of claim 138, further including:

receiving a coordinate transformation that maps points in an orthonormal coordinate system to points in the image; and

use said coordinate transform to determine at least one degree of freedom of the refined pose.

140. (new) The method of claim 138, further including:

determining, using the starting pose and the model pattern, an evaluation of reliability of at least some of the plurality of image boundary points, and a corresponding position along a boundary of the model pattern corresponding to at least some of the plurality of image boundary points.

141. (new) The method of claim 139, wherein the refined pose is computed using the starting pose, the plurality of image boundary points, evaluations, and corresponding positions.

142. (new) The method of claim 138, further including:

providing an evaluated pattern boundary point list that identifies boundary points in the stored model pattern that are not present in the run-time image.

143. (new) The method of claim 138, further including:

providing an evaluated image boundary point list that identifies boundary points in the run-time image that are not present in the stored model pattern.

144. (new) The method of claim 138, where the error value is a root-mean-squared error value.

145. (new) The method of claim 138, wherein the starting pose is determined by a template matching method.

146. (new) The apparatus of claim 145, wherein said template matching method employs normalized correlation.

147. (new) The apparatus of claim 145, wherein said template matching method uses digital re-sampling to determine at least one degree of freedom of the starting pose.

148. (new) The apparatus of claim 138, wherein the starting pose is determined by a generalized Hough transform.

149. (new) The method of claim 138, wherein the starting pose is a six degree-of-freedom coordinate transformation.

150. (new) The method of claim 138, wherein the starting pose is a coordinate transform that includes non-translational degrees of freedom.

151. (new) The method of claim 138, wherein the refined pose is a six degree-of-freedom coordinate transformation.

152. (new) The method of claim 138, wherein the refined pose is a coordinate transform that includes non-translational degrees of freedom.

153. (new) The method of claim 138, further including;

computing an evaluated pattern boundary point list that provides, for each of a plurality of said pattern boundary points, a numerical evaluation of the likelihood that the pattern boundary point was present in the run-time image.

154. (new) The method of claim 138, further including:

computing an evaluated image boundary point list that provides, for each of a plurality of said image boundary points, a numerical evaluation of the likelihood that the image boundary point was present in the stored model pattern.